

Chapter 47

Experimental Research of Pyrolysis Gases Cracking on Surface of Charcoal

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Abstract For several years, in the Joint Institute for High Temperatures of Russian Academy of Sciences, two-stage technology of biomass processing has been developing [1]. The technology is based on pyrolysis of biomass as the first stage. The second stage is high-temperature conversion of liquid fraction of the pyrolysis on the surface of porous charcoal matrix. Synthesis gas consisted of carbon monoxide and hydrogen is the main products of the technology. This gas is proposed to be used as fuel for gas-engine power plant. For practical implementation of the technology it is important to know the size of hot char filter for full cracking of the pyrolysis gases on the surface of charcoal. Theoretical determination of the cracking parameters of the pyrolysis gases on the surface of coal is extremely difficult because the pyrolysis gases include tars, whose composition and structure is complicated and depends on the type of initial biomass. It is also necessary to know the surface area of the char used in the filter, which is also a difficult task. Experimental determination of the hot char filter parameters is presented. It is shown that proposed experimental method can be used for different types of biomass.

47.1 Introduction

Biomass is the largest and the most important renewable energy source in the world. World production of biomass is estimated at 150–200 billion metric tons a year [2]. Biomass includes all variety of natural organics, agricultural wastes, industrial wastes, especially forestry and wood industry, paper mills, fast-growing plants, organic part of municipal waste.

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Biomass can be converted to energy in three ways: thermal conversion, chemical conversion, and biochemical conversion. In order to use the most effective of dry biomass thermochemical technologies such as burning, gasification and pyrolysis, which in spite of its effectiveness have some disadvantages.

Gasification is the most effective way to convert biomass is its conversion into combustible gas. However, the existing technologies of biomass gasification have several disadvantages. Air gasification is the easiest method to convert biomass into the gas. However, the resulting gas contains up to 60 % nitrogen and 40 % carbon dioxide. The calorific value of the gas is generally around 4–5 MJ/m³, which is too low for efficient use. Overall efficiency of gasification gas power plant is limited to 20 % [3].

Oxygen and steam gasification allow increasing the calorific value of the gas which contains no nitrogen and a small amount of carbon dioxide. The maximum gas yield reaches 1.3 nm³ per kg of raw material and its calorific value is about 11 MJ/m³ [4]. Steam gasification is the widespread process because of its simplicity. The main disadvantage of the process is concerned with necessity of steam generation, which reduces overall effectiveness of power plant. Use of oxygen for the purpose of gasification demands an air separation unit in technological chain that leads to rise in price of the end product. It should also be noted that purification of the gas from tar and ash is an urgent problem for all methods of gasification.

Along with gasification, pyrolysis is an effective method of thermochemical processing of biomass, industrial and domestic waste and at the same time one of the least-developed technologies of bioenergy. Pyrolysis is the of thermal decomposition process organics without oxygen. It runs at relatively low temperatures (500–800 °C) as compared with the processes of gasification (800–1,300 °C) and combustion (900–2,000 °C). Modern technologies of pyrolysis are focused to obtain a liquid product, so-called pyrolysis oil. Pyrolysis oil is a thick black tarry liquid close in composition to the biomass, and consists of a complex mixture of hydrocarbons with substantial water content (up to 30 %) and having a calorific value of about 20 MJ/kg [5]. Pyrolysis oil theoretically can be used directly as a fuel, but its wide use as a furnace fuel or motor requires more complex processing technology.

The technology of biomass thermal processing with synthesis gas production developed in the JIHT RAS is based on two stage thermal conversion of biomass with pyrolysis as first stage and high-temperature processing of the pyrolysis gases and pyrolysis oil on surface of char as second stage [1]. The method is similar to the one suggested in [6] and used in [7] for processing of wood waste and peat. Carbon, hydrogen and oxygen content of condensable and non-condensable volatiles allows them to be converted into synthesis gas consists of hydrogen and carbon monoxide in practically equal parts.

For practical implementation of the technology it is important to know the size of hot char filter for full cracking of the pyrolysis products on the surface of char. The most difficult is to determine the cracking parameters of tars, since their structure is complicated and depends on the type of initial biomass. To solve this

problem, there were a series of experiments showed the possibility of determining the minimum size of the hot char filter for the complete decomposition of volatile pyrolysis products.

47.2 The Experimental

The experimental set-up (Fig. 47.1) consisted of a high-temperature two-chamber fixed-bed reactor and a system of extraction and analysis of gas and vapor forming as a result of heating an initial raw material.

The reactor was a stainless steel tube with an inside diameter of about 37 mm, which was placed within two-section furnace with independent heaters for each section. The chambers were 300 mm length each. Raw material was placed into the chamber 1. Char obtained by pyrolysis of the same raw material was placed in the chamber 2. There were series of experiments with different amount of char placed in the chamber 2. Pyrolysis process was explored when chamber 2 was empty. Before experiments the top chamber was heated up to temperature 1,000 °C that was held further at the constant level. After that the temperature of the bottom chamber was raised at the rate 10 °C/min.

Pyrolysis gases formed during pyrolysis of initial raw material passed through the porous carbon bed with the fixed temperature. As a result of homogeneous and heterogeneous chemical reactions in the high-temperature zone, a decomposition of torrefaction gases took place. Conversion degree depended both on the temperature in the top chamber and on the residence time in a high-temperature zone. Non-condensable gas came into the volume meter (eudiometer). The samples of the gas were chromatographed.

Softwood pellets were used as a raw material for pyrolysis. Carbonized softwood pellets were used as the hot char filter. The properties of the pellets are shown in Table 47.1.

47.3 Results and Discussion

The results of measurements of the volume gas produced during pyrolysis per 1 kg of softwood pellets and subsequent cracking of tars shown in Fig. 47.2. From these data it follows that the cracking of tar on the surface of coal increases the volume of gas obtained by seven times.

The composition of non-condensable pyrolysis gas is shown in Table 47.2.

In the process of heterogeneous cracking on the surface of coal, methane and carbon dioxide decompose into hydrogen and carbon monoxide, forming the synthesis gas. Similar processes occur in the cracking of tars, acids, alcohols and water. The gas obtained in the cracking of tars consists almost entirely of hydrogen and carbon monoxide in roughly equal proportions.

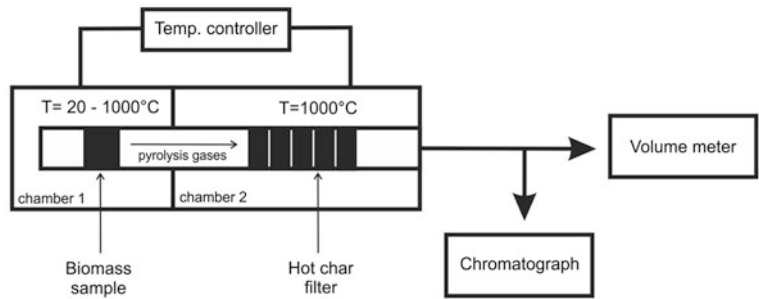


Fig. 47.1 Scheme of the experimental reactor

Table 47.1 Properties of softwood pellets (dry material, wt%)

Moisture	8.3
Ash	1.4
Volatiles	84.6
C	47
H	6
N	0.2
O	44

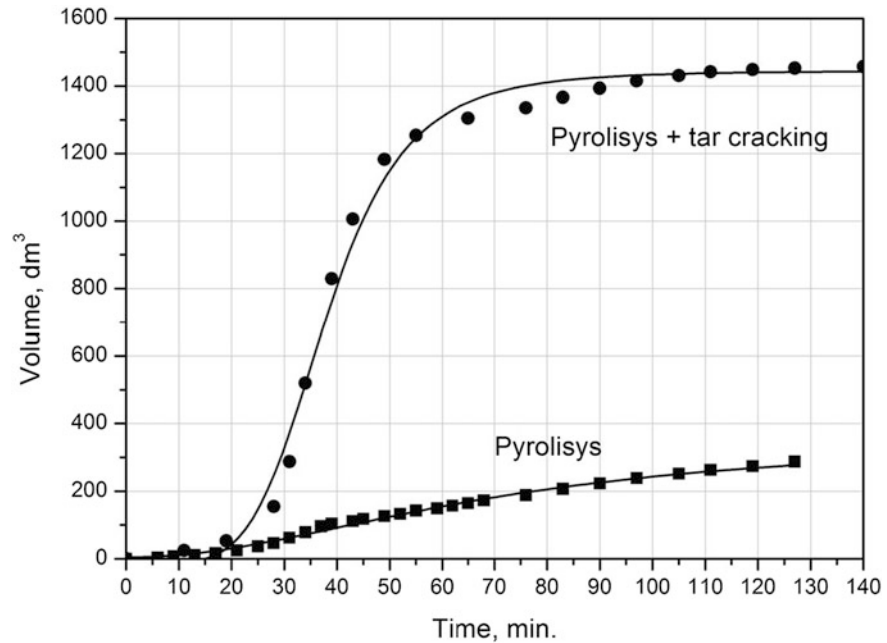
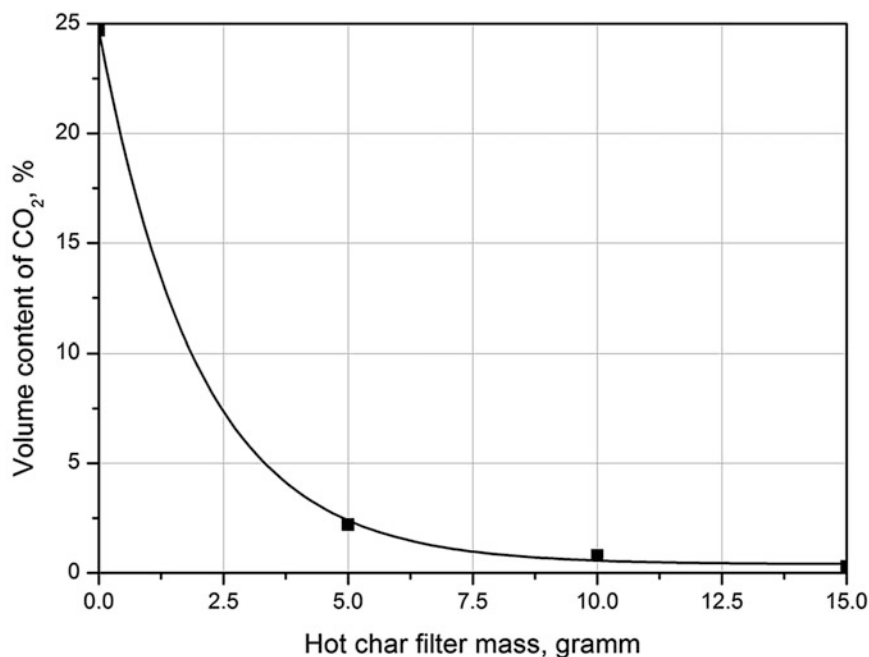


Fig. 47.2 Gas yield per 1 kg of raw material during pyrolysis of softwood pellets and subsequent cracking of tars

Table 47.2 Non-condensable pyrolysis gas composition

H ₂	CO	CO ₂	CH ₄	N ₂
32.6 %	22.4 %	24.1 %	16.3 %	4.6 %

**Fig. 47.3** The amount of carbon dioxide in the gas leaving the reactor at a different quantity of char in the cracking chamber

The cracking process of the pyrolysis products can be estimated by the amount of carbon dioxide in the gas leaving the reactor at a different quantity of char in the cracking chamber 2. This assumption is based on the fact that the activation energy for the secondary cracking of pyrolysis tars [8] is two times less than the activation energy for the Boudoir reaction [9].

For the estimation of the carbon dioxide amount, serial experiments were conducted, in which the chamber 2 was placed charcoal with mass of 5, 10 and 15 g. The mass of initial biomass in the chamber 1 was 5 g. The amount of carbon dioxide in the gas leaving the reactor at a different quantity of char in the cracking chamber 2 is shown in Fig. 47.3.

From these data it follows that charcoal in the chamber 2 works as a catalyst accelerating the decomposition process of carbon dioxide. Using charcoal filter that equal to the amount by weight of the initial biomass reduces the amount of carbon dioxide in the exhaust gas by more than order of magnitude.

Thus, using the charcoal filter is equal to the initial weight of the biomass is possible to achieve a high degree of decomposition of the pyrolysis products. Further increase in coal mass filter does not significantly increase the degree of decomposition.

47.4 Conclusion and Future Work

The data obtained show the possibility of experimental determination of parameters of carbon filter to achieve the desired characteristics of the gas produced two-step conversion of biomass. The method of determination the degree of decomposition condensed pyrolysis products on the content of carbon dioxide allows to estimate the required amount of carbon in the cracking chamber 2. However, the experiments were not considered processes of tars volumetric decomposition in the chamber 2. Additional experiments with increased sample weight of initial biomass for the same reactor size are necessary to be carried out. Moreover, for the application of this technology as a method of gas cleaning it is necessary to define the characteristic residence time of tars in the char filter that is sufficient for their complete decomposition.

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